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Elucidation of the part played by insects in the spread of plague—On the receptivity of different animals to plague infection.

An experimental study by Dr. GEO. H. F. NUTTALL, Berlin.

[Translated in this Bureau from the "Centralblatt für Bakteriologie und Parasiten Kunde."]

In 1894 Yersin stated, in his report on bubonic plague, "that flies contract the disease and die of it, and that they may serve as agents of transmission. I remarked many dead flies in the laboratory in which I made my animal autopsies. I caught one of these flies and having removed its wings, head, and feet, I steeped it in bouillon and inoculated it to a guinea pig. The inoculation liquid contained a great number of bacilli, precisely similar to the bacillus of plague, and the guinea pig died in forty-eight hours with specific plague lesions." (See *Annals of Pasteur Institute*, Vol. VIII, p. 667.)

The only other mention of flies in connection with plague, to my knowledge, was made by Haeser in 1882. He states that the city of Bengasi, in Tripoli, was attacked by plague in 1858-59, and lost two-thirds of its inhabitants, who numbered 10,000. Bengasi was a very dirty town, an on account of the number of flies there it was called by the Turks the "Kingdom of Flies."

Yersin's statement that the flies died of plague did not seem to me proven. Dead flies are often observed, especially in hot weather and in closed rooms. They probably die from want of water. It is also possible that the flies in Yersin's laboratory died of corrosive sublimate fumes. That the dead flies (observe that he reports examining one only) contained plague bacilli is no proof that they died of plague.

To decide this question I instituted the following experiments: The culture which I used came from a traveler from Bombay, who died of plague in London, and it killed mice in thirty-six to forty-eight hours. I received it from Dr. W. Kolle, who had it from Dr. Allan Macfadden.

INFECTION EXPERIMENTS WITH PLAGUE BACILLUS IN FLIES.

The flies (*Musca domestica*) were caught usually shortly before the experiment began and inclosed in a lamp cylinder closed with corks. The cylinders were about 30 centimeters in length and had a diameter of 5 centimeters. In the cylinder was placed a folded fly paper, on which it is observed flies light preferably. Both corks had an incision made for ventilation. These incisions were covered with fine wire netting. Into each cork was also fitted a tube for administering food. Only a small number of flies were placed in the apparatus. A drop of fluid food was placed on a folded piece of filter paper which was then passed through the tube. The cylinder was placed in a wire basket set in a bowl of corrosive sublimate solution to prevent the penetration of very small organisms through the wire-netting cover. The whole apparatus was then covered with a well ventilated bell glass.

The living flies were withdrawn by shaking through a glass tube inserted into the cork in the mouth of the cylinder, and passing into another similar cylinder or reagent glass. They were killed by a slight blow on the head by a glass rod passed into the second cylinder. Their contents were removed and inoculated to a mouse.

Experiment I.—Two apparatus were prepared at a room temperature of 12° to 14° C. One contained 6, the other 11 flies which had been caught four days before. The infected food (bouillon solution of fresh plague organs from mice dead thirty-six hours after inoculation) was renewed every two days. After eight days the flies were all alive and quite active. Six flies were then killed and inoculated to 2 mice. Two flies were still alive after eighteen days. The others had died by degrees. On microscopical examination plague bacilli were found in great numbers.

II. Three apparatus were prepared at a temperature of 14° C., and received, respectively, 9, 8, and 10 flies. The first two received infected food every twenty-four hours; the last served as control and received normal mouse organisms in bouillon.

The results are shown in the following table:

| Number of flies. | Dead after— | | | | | | |
|------------------|-------------|-----------|-----------|-----------|------------|------------|------------|
| | 24 hours. | 48 hours. | 72 hours. | 96 hours. | 120 hours. | 144 hours. | 168 hours. |
| 9 infected..... | 0 | > 2 | 4 | 5 | 6 | 6 | 9 |
| 8 infected..... | 0 | 0 | * 2 | 4 | | | |
| 10 control..... | 0 | 0 | 1 | 2 | 2 | 2 | 2 |

* Small.

III. Room temperature 14° to 16° C. Flies taken twenty-four hours previously in a bakery. They received infected food only during the first forty-eight hours.

| Number of flies. | Dead after— | | | | | | | |
|------------------|-------------|-----------|-----------|-----------|------------|------------|------------|------------|
| | 24 hours. | 48 hours. | 72 hours. | 96 hours. | 120 hours. | 144 hours. | 168 hours. | 192 hours. |
| 17 infected..... | 0 | 0 | 0 | 4 | 6 | 10 | 16 | 17 |
| 14 control..... | 0 | 0 | 0 | 1 | 1 | 3 | 5 | 6 |

IV. In a thermostat at 23° to 26° C. The flies were fed with bouillon during the first twenty-four hours after catching. At the beginning of the experiment they received bouillon infected with normal mouse organs. They had good ventilation and light and were protected against dryness.

| Number of flies. | Dead after— | | |
|-------------------|-------------|-----------|-----------|
| | 24 hours. | 48 hours. | 72 hours. |
| 21 infected | 9 | 18 | 21 |
| 5 control..... | 1 | 3 | 4 |

V. In thermostat at 28° C. At the beginning of the experiment all the flies had been without food for twenty-four hours. On receiving the infected food they took it eagerly. They were supplied with infected food during the first sixteen hours.

| Number of flies. | Dead after— | | |
|-------------------|-------------|-----------|-----------|
| | 24 hours. | 48 hours. | 72 hours. |
| 24 infected | 1 | 18 | 24 |
| 12 infected..... | 1 | 4 | 12 |
| 10 control | 1 | 2 | 6 |

VI. In thermostat at 26.5° to 31° C. The flies had been kept for forty-eight hours before the commencement of the experiment at 26.5° C.

| Number of flies. | Dead after— | | |
|------------------|-------------|-----------|-----------|
| | 24 hours. | 48 hours. | 72 hours. |
| 12 infected..... | 0 | 0 | 5 |
| 5 control..... | 0 | 0 | 1 |

The experiments were interrupted.

These experiments show that flies die when they are fed on plague material. Unfortunately a number of control flies died also. The average temperature of Hongkong during July, the hottest month, is about 31° C., and it would seem that Yersin must have made his observations on flies at that time. I therefore made that temperature the limit in my experiments.

Another fact of especial practical significance is the following:

Flies may live many days after they have taken infected food, and hence it can not be denied that they may play a part in the spread of plague, if they fall into food supplies or void their excreta into them. Many experiments that show living infected flies may, after remaining twenty-four or forty-eight hours and even longer in a clean apparatus, with no infected food, be full of virulent plague bacilli.

From a practical standpoint, and on the basis of these experiments, the utmost precautions should be taken against flies. Plague bodies should be covered immediately with cloths soaked in disinfectants. All excreta of the body should be disinfected. Food supplies should be kept covered. Ogata says that in localities infested with flies, fleas, and mosquitoes the plague patient should be kept under mosquito nets.

That other insects than flies may play a part in the spread of plague is stated from

different quarters. Hankin, in Bombay, found that mice and rats when inoculated with excreta of ants, which had fed on rats dead of plague, died in twelve hours. Hankin believes that ants spread the plague in Bombay. Ogata found that plague bacilli were on rats sick of plague. He thought they might inoculate with plague by their bite. This has not been experimentally shown, and the same is true of the influence of mosquitoes.

RECEPTIVITY OF OTHER ANIMALS TO PLAGUE.

(a) *The spontaneous outbreak of plague among animals.*—From recent publications we should derive the idea that the death of animals from plague was of recent observation. That it has, on the contrary, been long known will be shown by a glance at the literature on the subject.

Boccaccio states in the Decameron that he himself had seen 2 hogs die of plague in the streets of Florence (1348). Dogs, cats, and chickens died at other places. The bodies of animals dead from plague in Africa were observed by Haeser to be black. Birds which alighted on human plague corpses sickened and died. In Dalmatia the plague broke out first in animals. The death of cattle, horses, etc., is reported from different countries. Many of these animals doubtless die of other diseases. Birds fly from a plague-infected country. Haeser relates that fish disappeared when men and the domestic animals sickened. Nierphorus speaks, as quoted by Haeser, in his Byzantine History, that birds, domestic animals, horses, and house mice died of plague. Skene, of Edinburgh, says, in his report of the plague of 1868, that the death of chickens, moles, and snakes was the forerunner of a plague epidemic. "If domestic fowls become pestilential it is a sign of maest dangerous pest to follow."

Lodge says, in his treatise of the plague, London, 1603, "and when as rats and moles and other creatures (accustomed to live underground) forsake their holes and habitations, it is a token of corruption in the same."

In the present century it is reported that in 1836, at the time of the second epidemic at Pali, in India, a great mortality among the animals, but especially among the rats in the vicinity of the city, was observed. At the time of the plague epidemic at Kermaon and Gahrwal, in 1851, there were two huts in the vicinity of Dudoli in which 16 men were attacked with plague, of which number 14 died. Great numbers of rats in these huts died, while 30 head of cattle that occupied the huts were not affected. Rocher states that the bodies of Chinese, who died of the plague in the province of Junnan, were not buried, but exposed to the sun, which afforded the flies an excellent scope for their influence. The rats were first attacked. They left their holes in crowds, tumbled about and died. Buffalo and dogs were also affected. These facts are confirmed by many other observers.

During the last epidemic the death of animals from plague was frequently observed. Kitasato and Yersin examined dead rats and mice and isolated the plague bacillus. Lawson states that rats and mice did not die spontaneously of plague during the epidemic at Hongkong. Janson, in his article, "Black death among animals," states that official reports from Canton show that Chinese who had eaten hog flesh infected with plague were attacked with plague. It has been frequently observed that first rats and mice and then hogs and cattle begin to die before the disease attacks men. Ogata, in his report on plague in Formosa, says that plague was called there "Rat pest." He found plague bacillus in 6 rats found in the streets of Taihokus.

(b) *Plague artificially induced in animals.*—The following is a short statement of my experiments in inoculation, together with those of other authors:

Rats: Died two to four days after inoculation. (Kitasato, Yersin, and others.)

White rats: Died after fifty-four hours (2 animals). (Nuttall.)

White mice: Were less receptive than house mice and rats. (Wilm.) They behave very differently. Of 2 inoculated under the same circumstances, 1 died after forty hours, another after five and one-half days. (Nuttall.)

House mice: Die one to three days after inoculation. (Kitasato and Yersin.)

Field mice: Of 2 animals which were inoculated with a not perfectly virulent culture, 1 died of plague in six days; the other continued to live.

Guinea pigs: Died after two to five days. (Yersin and Kitasato.) Young animals died still sooner.

Rabbits: Died after two to five days (Kitasato); four to seven days (Wilm); two to six days (Ogata).

Monkeys: A monkey died five days after feeding with pure culture in sugar cane. Two other animals died spontaneously in the laboratory. (Wilm.)

Cats: Wilm observed 2 cats fed with bubo material. They were ill seven days, but recovered. Ogata saw cats (number not given) die after inoculation.

Chickens died usually three to four days after inoculation. (Wilm.) Are refractory according to Ogata.

Sparrows: One died after seventy-two hours. (Nuttall.)

Adders (*Pelius borus*): At 26° to 28° C. died of plague after forty-three hours. A control animal remained alive at this temperature, and was quite alert after two weeks. (Nuttall.)

Lizards (*Lacerta agilis*): At 21° to 26° C. one died of plague after thirty-six hours. Another remained alive for a week.

Swine: Lawson inoculated and fed swine with plague organs from man. They had fever, but recovered. (Lancet, July 27, 1895.) Wilm saw a hog die twenty-two days after feeding with human plague spleen. Ogata stated that swine died some days after inoculation.

Horses: I have never known a horse to die after inoculation, but the following shows that the horse may be receptive to plague: An entire gelatine culture, which had killed house mice in two days, was intravenously injected. A violent fever ensued, which lasted one week. Cure followed. (Yersin, Calmette, and Borrel, *Annals of Pasteur Institute*, Vol. IX, 1895, p. 594.) A quarter culture, subcutaneously injected, induced violent fever for forty-eight to sixty hours, with large tumor on spot of inoculation, which developed into an abscess.

When not otherwise stated, the animals were subcutaneously inoculated. I could not keep moles alive long enough to test their immunity. They do not bear captivity. In short, it appears that during plague epidemics in various countries the death of rats, mice, swine, cats, dogs, cattle (viz, buffalo, goats, horses, and mules), snakes, chickens, and birds has been observed and reported. By bacteriological examination it has been shown that rats and mice contract plague and die. It has been shown that plague may be experimentally induced, with fatal results, by feeding or inoculating with plague matter rats, white mice, house mice, field mice, wood mice, guinea pigs, rabbits, swine, monkeys, cats, chickens, sparrows, and flies. Pigeons, hedgehogs, and frogs are immune. Lizards and snakes are receptive at high temperatures, but are otherwise immune. Experiment with dogs and cattle is negative.

Further investigation in this field should prove interesting, if we consider the results obtained by Yersin, Calmette, and Borrel. These writers find that by inoculation of the same species of plague bacillus from animal to animal a definite degree of virulence is obtained. "The microbe which kills the mouse in two days, when it is carried through the rabbit, requires, in its first transition, considerable time to cause the death of that animal. After several passages it kills the rabbit regularly in three days, but it has then lost its virulence for mice, and some passages from mouse to mouse are needed to restore it."

BERLIN, *July 15, 1897.*

BRAZIL.

Sanitary report from Rio.

RIO DE JANEIRO, *July 19, 1897.*

SIR: I have the honor to transmit report for the week ended July 17, 1897:

There were 12 deaths from *accessio pernicioso*, an increase of 9; 2 from yellow fever, none in the foregoing week; 1 from beriberi, a decrease of 4; 1 from enteric fever, the same as in the foregoing week; 3 from measles, an increase of 2; 47 from tuberculosis, an increase of 9, and 273 from all causes, an increase of 5.

Smallpox in Para.—A telegram from Para this morning states that smallpox is prevalent there in epidemic form.

The health of this town continues good.

Since last report the following-named ships have been inspected or received bills of health from this office: July 13, ship *Deccan*, British, for New York. July 15, bark *Julius*, Portuguese, for Pensacola, and steamship *Hathor*, British, for St. Lucia, West Indies. July 16, steamship *Netherfield*, British, for Hampton Roads, Va.; bark *Lerak*, British, for Delaware Breakwater, and bark *Venturoso*, Portuguese, for Philadel-